

Quality indices of municipal solid waste compost for safe use in agriculture



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Foreword

Solid waste management is one of the essential services to be provided by municipal authorities in the country to keep urban areas clean. However, the service is still poor with the existing management system being unscientific, outdated and inefficient. Indian cities generate huge amount of solid waste amounting to more than 42 million MT every year. Presently, only about 10% of the city waste is used for producing composts and rest is off-loaded haphazardly at dump-yards situated within or outside the city. The dumping sites emanate foul smell and become breeding grounds for flies, pests and diseases.

Although composting of solid waste serves the twin objective of cleaning cities and production of valuable organic manure, it is still followed in a few municipal areas. The poor quality of composts also remains a major concern of consumers and quality control regulating authorities. Hence, a need is felt to identify constraints in generation of good quality city waste composts and develop a tool for their quality evaluation. Needless to say, the use of good quality city waste composts would promote IPNS for sustained soil health and crop productivity.

I admire the team of scientists of IISS, Bhopal for the sincere and dedicated efforts in characterizing the city waste composts produced in different municipal areas of the country and developing a method for their quality assessment. I am sure, this bulletin will serve as a guideline for different stakeholders in improving the existing urban solid waste management system in the country.

P. D. Sharma

(P. D. Sharma)

December, 2008

Preface

Assessment of quality of municipal solid waste composts has always remained a subject of controversy in several countries in respect of purpose, parameters and regulatory limits. In all of the cases, however, central issue remained same, viz., recycling of wastes for beneficial purpose and protection of environment. In accordance with the mandate, Indian Institute of Soil science has always given emphasis on integrated nutrient management in its research programme as a tool to enhance plant nutrient supply so that country's food production can be increased and sustained. Solid waste compost, though is a potential component of INM system, is viewed skeptically by the farmers as probable polluter of soil resources. In order to protect the interest of various stakeholders, especially farmers, quality control limits have been defined for marketable MSW composts; but the manufacturing firms have not welcomed it on the points of achievability of desired limiting values. Therefore a need was felt to assess the physical, chemical, nutritional and heavy metal characteristics of MSW composts produced across different geographical locations of the country in order to have a platform for re-look into the existing quality control guidelines and developing a system of differentiating 'Good' quality composts from inferior ones, which can be a useful tool by various stakeholders. With this background, this study has been conducted under an Institute project at the constant inspiration of our Director.

Investigators of the project express deep sense of gratitude to ICAR for giving an opportunity to conduct an investigative study on this aspect and also gratefully acknowledge the support and guidance of Dr. A. Subba Rao, Director, Dr. S. Kundu, Head of Division of Environmental Soil science and all the Scientists of IISS, Bhopal for their valuable support, guidance and suggestions during the entire period of investigation. For successful execution of the project, authors express sincere gratitude to Technical and supporting staff of Division of Environmental Soil Science. We hope that outcome from this study will be useful to planners, administrators, farmers, producers as well as market economists.



J.K. Saha
Principal Investigator

Contents

Sl. No.	Topic	Page No.
1.	Introduction	1
2.	Objectives of the study	2
3.	Amount and Nature of solid wastes generated in Indian cities	3
4.	Existing methods of composting of municipal solid wastes	4
5.	Methods of analysis of compost samples for different quality parameters	11
6.	Physical and chemical properties of the MSW composts	12
7.	Manurial value of MSW composts	15
8.	Pathogenic contamination in MSW composts	19
9.	Heavy metal contamination in MSW composts	20
10.	Compliance of MSW composts to Quality Control (QC) Guidelines	23
	(a) Compliance in respect of physical, chemical and fertility parameters	24
	(b) Compliance in respect of heavy metal contents	26
11.	Grading of MSW composts for their quality in respect of manurial value and environmental safety	30
	(a) Grading according to fertilizing and soil conditioning potential	31
	(b) Grading according to heavy metal pollutant content	33
12.	Compost quality index	34
13.	Classification of MSW composts on the basis of quality indices values	35
14.	Salient findings and conclusions	40
15.	Recommendation	42
16.	References	44

1. Introduction

There has been a significant increase in municipal solid waste generation in India in the last few decades. This is largely due to rapid population growth and economic development in the country. Solid waste management (SWM) has become a major environmental issue because of serious environmental implications like global warming (through green house gases emission) and contamination of toxic pollutants (like heavy metals) in surface and groundwater bodies.

Composting MSW is seen as viable option in urban SWM for better utilization of organic waste materials as this process helps in creating a product, at a selectively low cost that is suitable for agricultural purposes. Presently, a very small fraction (8 - 9%) of the MSW generated is used for compost production by various public or private enterprises. However, these entrepreneurs are facing tremendous problems in marketing and distributing their products. One of the major causes for poor marketing is poor quality of MSW composts produced.



Photo 1: In most cities, solid wastes are dumped and burnt causing considerable environmental pollution

Although Ministry of Environmental and Forest, Govt. of India formulated Municipal Solid Wastes (Management and Handling) rules, 2000 and indicated waste processing options including standards for

composting under Schedule IV, these were complied in very few municipalities (CPCB 2000). There is wide variation among the compost-manufacturing agencies with respect to technology/ method of composting like composting facility design, source and nature of waste, composting procedure and length of maturation, which are likely to influence the quality of MSW compost produced.

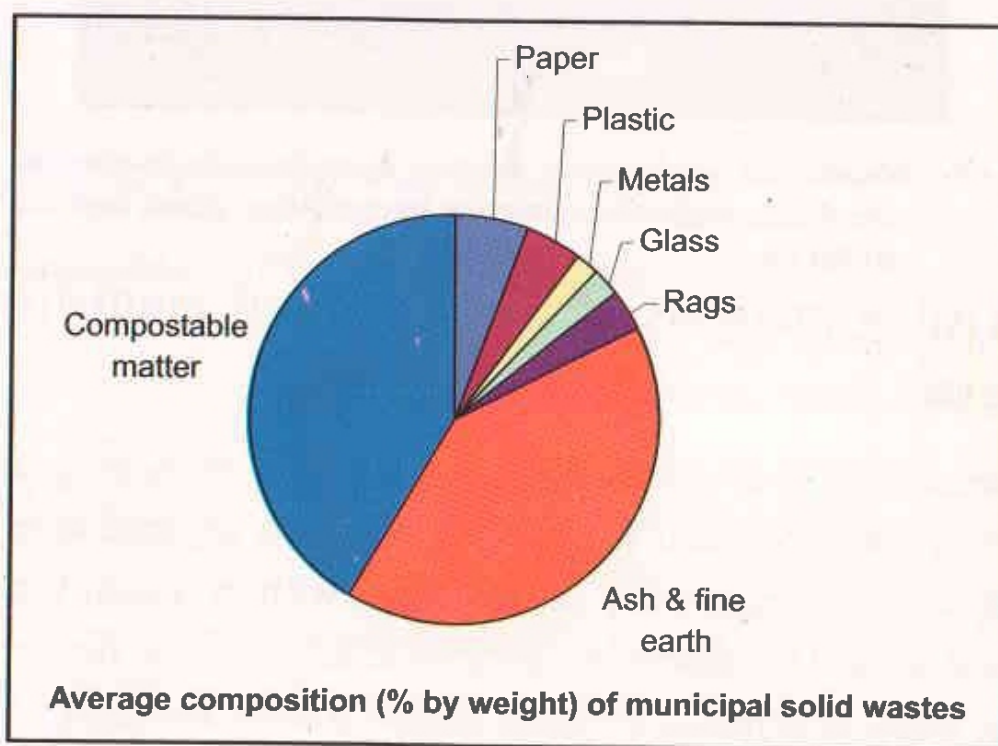
Applications of composts have been reported to improve physical, chemical and biological properties of soils, resulting in higher crop yield and quality. Supply of nutrients to plants is one of major considerations for utilizing composts for soil productivity. The recent surge of interest in composting of waste materials for use in crop production has led to development of new regulations to ensure appropriate nutrient supplying potential as well as to control contaminants and insure safety of environment including human health. Such regulations, generally define minimum level of organic matter as well as major nutrients and maximum total concentration of contaminants (e.g. heavy metals) permitted in the finished compost. In India, 'The Fertilizer (Control) Order 1985' (FAI, 2007) has been put forward to regulate the marketing of city waste composts. However, there is a lack of comprehensive information on the nature of composts produced in light of the existing quality control limits for different parameters.

2. Objectives of the study

A study was, therefore, undertaken with the objectives of (1) characterization of different quality control parameters of the composts produced from municipal solid wastes in different cities of India; (2) reviewing/proposing modification on the existing quality control guidelines; and (3) developing a method of assigning quality indices for the purpose of grading the composts in accordance to their fertilizing value and magnitude of environmental threats due to heavy metal contents.

3. Amount and Nature of solid wastes generated in Indian cities

A CPCB sponsored study conducted by NEERI on 59 selected cities of India revealed that waste generation rate varied from 120 to 600 g per capita per day with an average value of 400 g per capita per day. Average per capita waste generation increases as size of the city increases (NEERI, 1995). The study conducted during the year 2004 - '05 also indicated that total solid wastes generated in these cities was 39031 tonne/day. Considering, present urban population of 330 million, about 47 million tons of solid waste is estimated to be generated each year. Cities with more than one lakh population contribute 72.5% of the waste generated in the country as compared to other 3955 urban centers that produce only 17.5% of that total waste (MOUD 2005).



Characterization studies carried out by NEERI (1995) indicate that MSW contains large organic fraction (30-40%), ash and fine earth (30-40%), paper (3-6%) along with plastic glass and metal (each less than 1%), calorific value of refuse ranges between 800-1000 kcal/kg and C/N ratio ranges between 20 and 30. Ideally, the compost feedstock should

only contain compostable materials such as food scraps, paper, cardboard, yard waste, and wood. Noncompostable waste (glass, metals, and plastics) contaminates the municipal solid waste to varying degrees. Considering an average collection efficiency of about 70%, country has the potential of producing about 2 million tons of compost each year if such wastes are properly used for composting.



Photo 2: Municipal solid wastes contain considerable proportions of non-biodegradable materials like plastics, glass, metals, fine earths etc.

4. Existing methods of composting of municipal solid wastes

Composting municipal solid waste involves managing conditions to accelerate the biological decomposition of its organic components. End product is an organically rich product with potential benefits for agricultural soils. The conditions for efficient biological decomposition of organic waste depend on optimum temperatures (50 - 65° C), moisture (45 - 55%), aeration (>15% O₂), pH (6.0 - 7.5), levels and carbon to nitrogen (25:1 - 30:1) ratios of the feedstock. If conditions deviate from these optimum conditions, the composting process is slowed and chemically unstable (immature) compost may be produced. When microorganisms degrade the organic materials under optimum oxygen levels, the process is called aerobic composting. In contrast, a different

group of microorganisms can degrade the organic material under limited oxygen levels, where the process is called anaerobic composting. Aerobic composting is usually preferred over anaerobic composting because it is faster in biological oxidation and does not generate as many foul odors (i.e., ammonia, sulfur compounds, and organic acids).



Photo 3: Composting of non-segregated wastes in small heaps at Shimla

Composting methods followed in Indian cities

In pursuance of the directions of honorable Supreme Court of India, the ministry of urban development and poverty alleviation government of India constituted an Inter-Ministerial task force on integrated plant nutrient management using city compost. The report submitted in 2005 by the task force brought out various relevant issues and made some suggestions on composting particularly technical and financial requirements for setting up of compost plant as a viable option for promoting integrated plant nutrient management. However, majority of different cities do not have any facilities for composting even if, Municipal Solid Wastes (Management and Handling) rules, 2000 has been implemented to a certain extent.

According to report by CPCB regarding implementation status of Schedule-IV, composting facilities existed in 63 cities of fourteen states

and were proposed to start in another 56 cities. From these existing facilities, we collected 34 municipal solid waste composts from 28 cities of 12 states of the country. The samples were collected once from each place by following methods of US-EPA part 503 rule (composite sample of several grab samples combined). Source of compost samples collected are presented in Table 1. The information on sources and types of MSW wastes, their processing at various stages and methods of composting were collected from the manufacturers of the composts.

Windrow method of composting is followed by about 72% of the manufacturers, where mostly non-segregated or partially segregated wastes are allowed to decompose for several months with or without turning. Composting is performed in concrete pits in 4 sites; viz, Kullu, Manali (developed under Indo-Norwegian project), Vijaywada and Namakkal. For proper and speedy decomposition of biodegradable segment of the waste, addition/spraying of inoculants of microbes are done in majority of the composting plants. In 23% manufacturing sites, vermicomposting is being adopted for producing good quality composts in shorter time.



Photo 4: Composting of partially segregated municipal wastes in pits prepared under Indo-Norwegian project at Kullu, Himachal Pradesh



Photo 5: Composting of municipal solid wastes segregated at source by Suryapet municipality (A.P.) using earthworms

Pre-processing and post-processing methods followed during composting

Pre-processing generally involves segregation of biodegradable organic fractions from rest of the wastes, which mainly composed of paper, plastics, glass, metals etc. While biodegradable organic fractions are taken to composting yards, remaining fractions are either dumped in landfill site or are segregated further to remove recyclable materials like papers, plastics and glass etc., as followed by Suryapet municipality of A.P.



Photo 6: Shredding machine at Suryapet (AP) pulverizes the solid wastes so as reduce the time for composting



Photo 7: Segregated solid wastes are collected door-to-door from every household on a specially designed tri-cycle with red bin (non-biodegradable) and green bin (biodegradable) and taken to composting yard.



Photo 8: Segregated solid wastes are collected door-to-door from every household on a tractor driven trolley with separators for biodegradable wastes, dry recyclable wastes and other non-biodegradable wastes.

Pre-processing of wastes is not followed at all in majority (about 45%) of the sites where non-segregated wastes are dumped in heaps and left for several months with or without turning for decomposition of biodegradable wastes (termed as 'non-segregated'). In some of the composting plants (26%), big size non-biodegradable wastes, like papers, plastics, rubber, metals etc. are manually removed prior to



Photo 9: Paper, plastics, glass and metals are sorted out from dry garbage by Suryapet municipality and sold out to scrap dealers for their recycling.

composting (termed as 'partially segregated'). In rest of the cases, biodegradable wastes are segregated at generator level and this is done in two ways. In few cities (Namakkal, Suryapet and Vijaywada), individual households delivers segregated biodegradable wastes separately during 'door-to-door' collection by municipal organization which are composted in pits or windrows using earthworms. In several other cities, sources generating mainly biodegradable wastes, like hotels &



Photo 10: Large Mechanical composting plant installed at Dhapa (Kolkata city) for post-processing of MSW composts

restaurant, vegetable market, slaughter house etc. are selected for feedstock collection for composting plants. Wastes collected through these two methods for compost preparation will be subsequently termed as 'segregated wastes'. In many of the composting yards, microbial cultures are also added to the wastes in order to hasten the process of composting.

Post-processing methods mainly involve air-drying of the composts followed by their sieving, either mechanically or manually to remove bigger size inerts. Mechanical composting plants are installed by big enterprises in many cities like Kolkata, Nashik, Bhopal, Delhi, Shimla, Solan. However, in many cases, machinery and other equipment are larger in their handling capacity than required for the quantity of wastes generated in the city.



Photo 11: In small towns and cities, post-processing involves mainly manual sieving of waste composts

Table 1: Source, type of segregation and method of composting in case of MSW compost materials collected

City type	Segregation before composting	City
Metro (> 4 million population)	Non-segregated	Mumbai, Delhi-1, Kolkata, Bangalore-1, Bangalore-2
	Segregated	Delhi-2
Big (1-4 million population)	Non-segregated	Pune-1, Pune-2, Varoda, Bhopal
	Partially segregated	Nashik, Aurangabad, Ahmedabad
	Segregated	Nagpur
Medium (0.2 - 1 million population)	Non-segregated	Berhampore-1, Berhampore-2, Bhilai, Raipur,
	Partially segregated	Latur, Trivandrum-1, Trivandrum-2
	Segregated	Tiruppur
	Segregated	Korba, Vijaywada-1, Vijaywada-2, Parbhani
Small (< 0.2 million population)	Non-segregated	Solan, Junagarh, Shimla
	Partially segregated	Kullu, Manali
	Partially segregated	Puri
	Segregated	Namakkal, Suryapet

5. Methods of analysis for different quality parameters

The MSW compost samples were processed and analyzed for different fertilizing & soil conditioning parameters like gravimetric moisture content, bulk density, pH, electrical conductivity, total organic carbon (TOC), total nitrogen (N), total phosphorus (P), total potassium (K), pathogenic organisms total Coliform and Salmonella population count as well as contents of heavy metals zinc (Zn), copper (Cu), cadmium (Cd), lead (Pb), nickel (Ni) and chromium (Cr) following standard procedures. For analysis of different fertility parameters and heavy metal contents, methods mentioned by Page et al. (1982) were followed with some modifications as and when required.

6. Physical and chemical properties of the MSW composts

The range and median values of physical and chemical properties of the MSW composts collected from 28 cities are presented in Table 2.

Moisture content: Moisture in the composts varies widely owing to the difference in source material, method of composting and conditions and period of storage. Moisture content in the compost samples varied from 3.6 to 45.4% with a median value of 17.2%. On an average, MSW composts prepared from segregated wastes had higher moisture content than those prepared from non-segregated wastes. (Table 3). Although moisture content in the composts is not an important quality parameter in terms of nutritional value, it may provide some understanding of processing or storage conditions and also ease of volume of handling and transport. Composts with less moisture contents may not have been fully stabilized or may have been stored for long periods leading to moisture loss. While excessively dry composts are often dusty and unpleasant to handle, compost with too high a moisture content become too clumpy and increase transportation cost.

Table 2. Physical and chemical properties of the municipal solid waste composts produced in different cities in India.

Parameters	Minimum	Maximum	Median	RSD(%)
Moisture (%)	3.63	45.37	17.24	56.4
Bulk density (g cm ⁻³)	0.52	1.15	0.86	19.5
> 4 mm (%)	0.00	16.13	0.58	774
pH (1:5)	6.64	9.63	7.45	6.9
EC (dS m ⁻¹)	0.52	8.41	2.97	59.8
Chloride (mg kg ⁻¹)	0.20	3707.0	575.0	152.5
Total organic C (%)	5.22	22.15	11.33	41.1
Total N (%)	0.26	1.71	0.61	67.6
Total P (%)	0.08	0.73	0.16	69.6
Total K (%)	0.12	1.31	0.44	59.3
C : N ratio	7.19	36.53	16.64	47.30

Bulk Density: Bulk density on dry weight basis generally indicates organic matter as well as inert material/ash content. Composts with lower bulk density are desirable as it increases water holding capacity of soil when applied continuously for longer period of time. However, composts prepared from municipal solid wastes invariably contain higher bulk density than those prepared from farm wastes in rural area due to higher content of siliceous materials like soil, dust, glass as well as metals etc. The Bulk Density values of the MSW composts varied widely (RSD 20%) ranging from 0.52 to 1.15 g cm⁻³ with median value of 0.86 g cm⁻³ (Table 2).

Mean bulk density value is slightly lower in case of composts prepared from segregated (fully or partially) solid wastes as compared those prepared from non-segregated wastes, which may be due to the use of higher decomposable material during composting in former method.

Table 3: Effect of segregation of wastes on the physical and chemical properties of composts

Parameters	Non-segregated	Partially segregated	Segregated
Moisture (%)	13.41	17.29	25.53
Bulk density (g cm ⁻³)	0.91	0.85	0.83
pH (1:5)	7.38	7.46	7.54
EC (dS m ⁻¹)	2.34	2.88	3.71
Chloride (mg kg ⁻¹)	601.31	1015.26	989.81
Total organic C (%)	9.98	11.95	13.92
Total N (%)	0.62	0.69	1.02
Total P (%)	0.16	0.15	0.27
Total K (%)	0.46	0.54	0.50
C:N	17.94	19.24	22.73

There was no significant variation in the total P content in MSW composts from different city sizes. However, segregation of decomposable wastes had significantly improved total P content in the composts prepared (Fig. 2). Mean P content in composts prepared from segregated wastes was about 69% more than the composts prepared from non-segregated wastes.

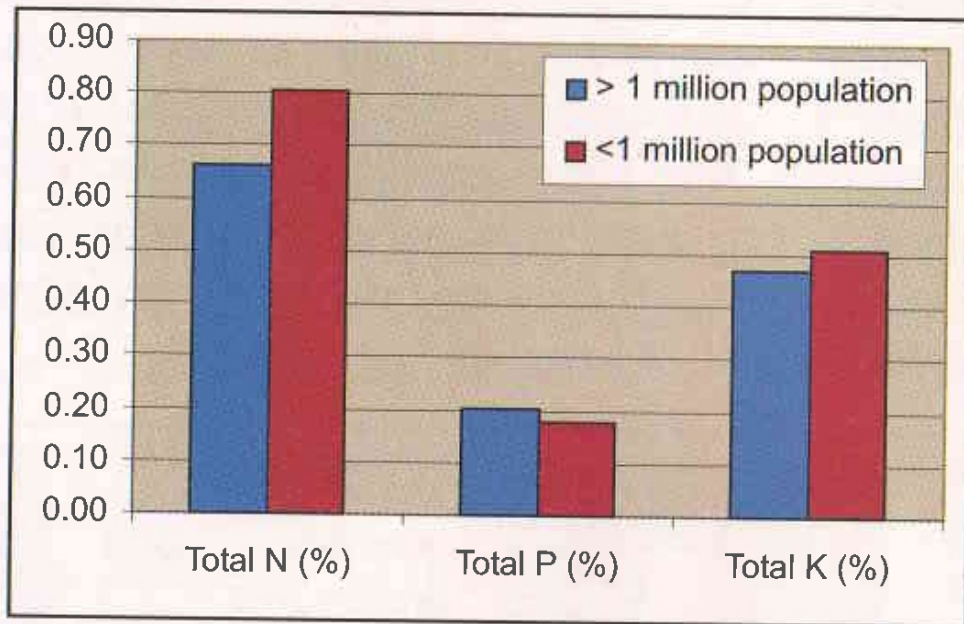


Fig. 3. Effect of city size on major nutrient content in MSW composts

Total K: Potassium is another important major plant nutrient and hence, its content is determined for evaluating quality of composts. Total K in MSW composts varied from 0.12% in sample from Berhampore to 1.31% in the sample from Tiruppur with an median value of 0.44% (Table 2). Average K contents were found almost similar in the samples from different city types, namely, metro, big, medium and small. Similarly, composts prepared from either segregated or non-segregated wastes had similar K contents.

Carbon - Nitrogen ratio: Compost carbon to nitrogen ratio (C: N) is considered as an indicator for their maturity with respect to organic matter and N cycling. In relevance to solid or any other growth media, mature compost can be incorporated without causing excessive immobilization or NH_3 toxicity. This ratio is usually measured for assessing maturity for composts derived from high C:N mixture (initial

C:N ratio > 25:1). Plants grown in fields amended with composts with high C:N ratio immobilize N and are often yellow or stunted because of N deficiency.

In the present survey study, C:N ratio in the compost samples ranged from 7.2 to 36.5 with an median value of 16.6 (Table 2). The main reason for decreasing C:N ratio of waste feedstock during composting is the decomposition of organic materials resulting in higher loss C (as CO_2 and CH_4) compared to N.

The MSW composts prepared from segregated wastes had the highest mean C:N ratio (22.73) as compared to those prepared from partially segregated wastes (19.24) and non-segregated wastes (17.94) (Table 3). The ratio did not vary significantly with size of cities.

8. Pathogenic contamination in MSW composts

Pathogens are disease causing organisms, such as certain bacteria, viruses and parasites which, if present in the composts in substantial amount can cause illness in human beings during their handling. Harmful pathogens like Salmonella and Coliform bacteria can enter in the solid wastes through disposable diapers, faecal materials and hospital wastes etc. However, as the temperature rises during composting period, these pathogens are usually destroyed as they reach their thermal death point.

The composts collected from different cities were subjected to enumeration of total Coliform and Salmonella population. Salmonella could not be detected in any of the compost samples collected from different cities. Total Coliform (responsible for enteric diseases) was detected ($>10^3$ cfu/g) only in 17% samples collected and these belonged to six cities, namely, Kullu, Manali, Shimla, Kolkata, Trivandrum and Sirsa.

9. Heavy metal contamination in MSW composts

Heavy metals enter into the municipal solid wastes due to extensive use of synthetic materials like electronic equipments, paints, industrial products etc. in the modern day urban society. As a result, municipal solid waste composts generally contain heavy metals in concentration higher than those found background soils. This results in rising concerns about their indiscriminate use in agricultural land. Therefore, heavy metals content is considered another important quality parameter to indicate the extent of threat perceived by the soil and water resources from getting polluted. Results of heavy metals analysis of the MSW composts are presented in Table 5.

Table 5: Median and variation of heavy metal contents in MSW composts of Indian cities

Metal	Minimum	Maximum	Median	RSD (%)
Zn (mg kg ⁻¹)	82.39	945.61	252.46	81.01
Cu (mg kg ⁻¹)	24.88	864.86	198.07	113.65
Cd (mg kg ⁻¹)	0.00	8.43	0.99	174.60
Pb (mg kg ⁻¹)	10.82	646.72	133.49	108.24
Ni (mg kg ⁻¹)	8.60	190.49	25.31	133.54
Cr (mg kg ⁻¹)	13.56	400.99	68.94	126.29
Fe (%)	1.15	7.49	2.45	64.24
Mn (%)	276.50	1577.83	724.67	47.62

Heavy metal contents in the MSW composts collected from 34 different sources ranged between 82.4 - 945.6 mg/kg for Zn, 24.9 - 864.9 mg/kg for Cu, trace - 8.4 mg/kg for Cd, 10.8 - 646.7 mg/kg for Pb, 8.6 - 190.5 mg/kg for Ni and 13.6 - 401.0 mg/kg for Cr and the corresponding median values were 252.5 mg Zn/kg, 198.1 mg Cu/kg, 0.99 mg Cd/kg, 133.5 mg Pb/kg, 25.3 mg Ni/kg and 68.9 mg Cr/kg, respectively.

Further scrutiny of the results indicated that median value of heavy

metal contents in MSW composts from bigger cities (>1 million population) were higher by about 95% for Zn, 215% for Cu, 182% for Cd, 158% for Pb, 96% for Ni and 76% for Cr as compared to those in case of smaller cities (<1 million population) (Fig. 4).

A survey on physical characteristic of municipal solid waste (NEERI, 1995) indicated that cities with more than 1 million population generate higher average per capita wastes (270-500 g/capita/day) compared to smaller cities (210-250 g/capita/day). Also, wastes from the former group of cities was found to contain about 84% more metals as compared to small cities (>1 million population). Heavy metals from these metallic fractions of wastes might have contaminated the composts prepared in the municipal areas of bigger cities.

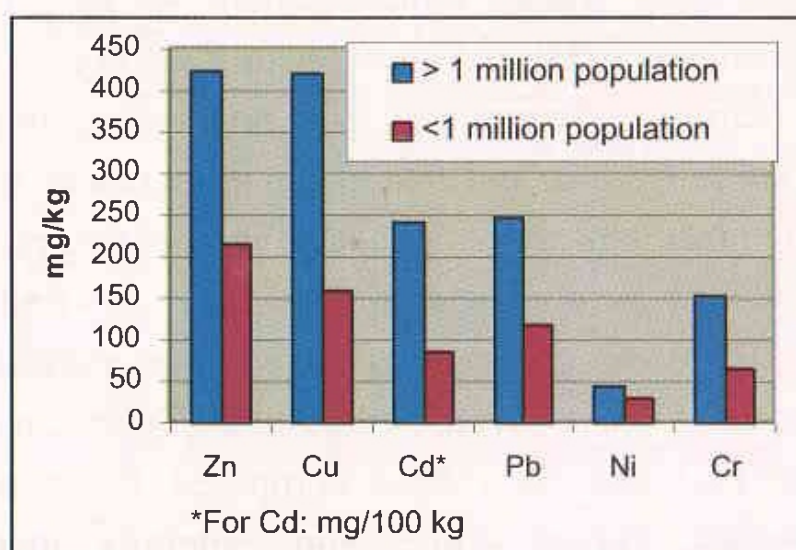


Fig. 4. Effect of city size on heavy metal contents in MSW composts

It has been found that composts prepared from non-segregated wastes contained higher mean concentration of all heavy metals followed by those prepared from partially segregated wastes and fully segregated wastes (Fig. 5). Mean value of heavy metals in the composts prepared from non-segregated wastes were more by 38% for Zn, 53% for Cu, 152% for Cd, 49% for Pb, 41% for Ni and 68% for Cr as compared to composts prepared from partially segregated wastes; and were more by 147% for Zn, 347% for Cu, 139% for Cd, 527% for Pb, 127% for Ni and 165% for Cr as compared to composts prepared from segregated wastes.

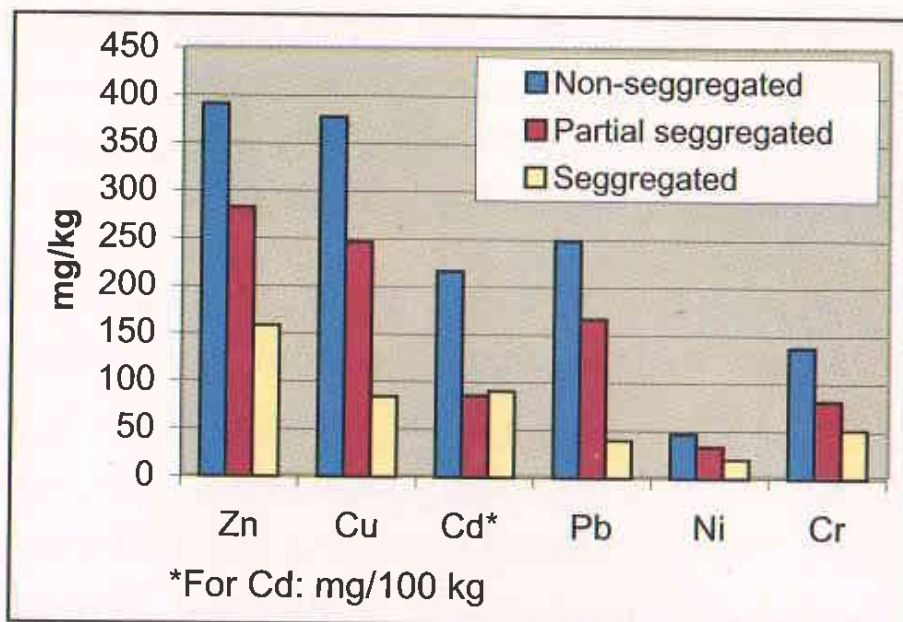


Fig. 5. Effect of segregation on heavy metal contents in MSW composts in Indian cities

Municipal solid wastes contain about 40-50% inert materials including toxic metal containing glass, metals, dusts etc. In about half of the locations, composts are prepared from non-segregated wastes where possibility of solubilization and absorption of metals on to fine particles exists. Although mechanical sieving after composting process removes all the coarse inert materials, metal rich finer particles find their way into final product. Even the compost prepared from partially segregated wastes contain more heavy metals; viz., Zn (by 78%), Cu (by 192%), Pb (319%), Ni (61%) and Cr (58%) compared those prepared from segregated wastes. Partial segregation generally involves manual separation of larger inert materials, viz., paper, plastics, rubber, leather, glass, and metals etc. at the site before subjecting these to composting. However, the degree of segregation of such metal containing wastes at composting site may not be complete as in case of almost complete segregation followed at source, like door-to door collection of biodegradable wastes and collection from selected sources like hotels & restaurant, vegetable market, slaughter house etc. This resulted in higher heavy metals contents in composts prepared from partially segregated wastes compared to those prepared from segregated wastes.

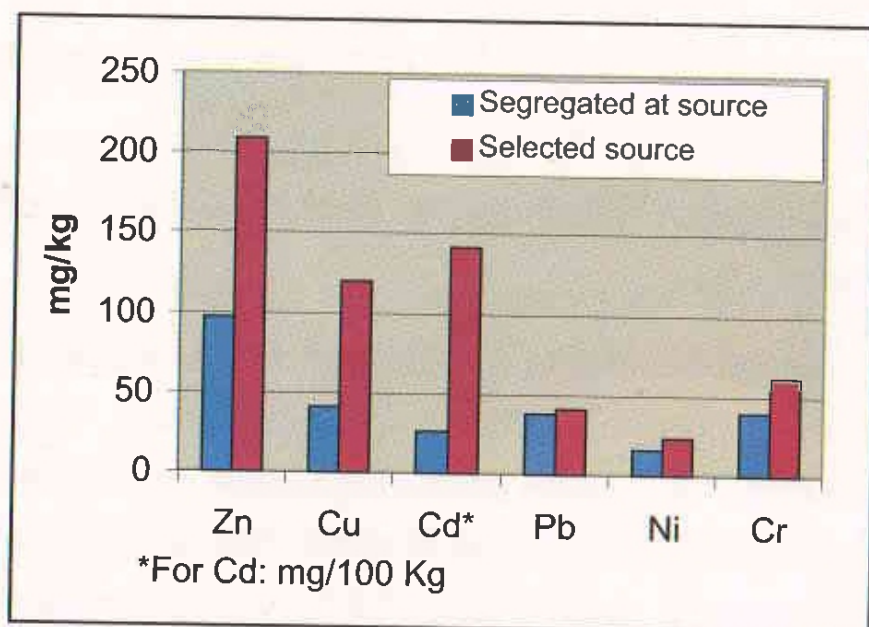


Fig. 6. Effect of type of segregation on heavy metal contents in MSW composts

In some cities, viz., Namakkal, Suryapet and Vijaywada, MSW composts have been prepared from decomposable wastes which were segregated at individual households through separate buckets for biodegradable and nonbiodegradable/recyclable/dry wastes. Such composts contained significantly lower content of heavy metals, viz., Zn (by 58%), Cu (by 68%), Cd (77%), Ni (by 37%) and Cr (by 38%) as compared to composts prepared from wastes which had been collected from places known to generate mainly biodegradable wastes like, vegetable market, hotel & restaurants, slaughter house etc (Fig. 6). This indicates that composting plants using wastes from these selected sources might have been contaminated with some other metal rich wastes.

Total Zn, Cu and Cr concentrations were found to correlate with all the heavy metals concentration in MSW composts. Besides these three heavy metals, Pb and Ni also correlated significantly with each other.

10. Compliance of MSW composts to Quality Control (QC) Guidelines

Quality control (QC) criteria for city waste composts in India put forward by The Fertilizer (Control) Order 1985 (FAI, 2007) has been

used to examine the status of compliance by the MSW compost samples collected from 28 cities.

(a) Compliance in respect of physical, chemical and fertility parameters

Results presented in Table 6 indicated that degree of compliance varied widely in respect of different QC parameters. While, quite a significant proportion of samples conformed to the permissible ranges in respect of bulk density, pH, EC, total N and C:N ratio; the compliance in respect of total organic C, total P and total K was very poor. Only 15%, 21% and 9% samples had respectively total organic C, total P and total K more than the permissible limit. Non-segregation of biodegradable wastes before composting can be ascribed as one of the major reasons for such poor compliance in respect of these important fertility parameters. Even in case of MSW composts prepared from segregated wastes, QC compliance in respect of total organic C and total K was quite low where only 22% and 11% samples respectively contained these elements more than the permissible limit. This indicates that there is a need for modification in the QC guidelines for MSW composts particularly with respect to minimum total organic C and total K contents so that MSW composts prepared from segregated wastes may pass through the QC guideline.

Accordingly, the following modifications are proposed on the existing QC fertility parameters:

- (1) Bulk density of MSW composts is highly related to organic matter content (correlation coefficient 'r' between TOC and bulk density is -0.86; significant at 1% probability level). Analytical precision of bulk density measurement varies widely with skill of analysts as compared to the measurement of total organic C. Therefore, 'bulk density' can be deleted from the list of QC protocol, when TOC is included.

- (2) QC limit for TOC can be lowered from the existing value of 16% to 14%, keeping in view of the mean value (13.92%) obtained in this study for MSW composts prepared from the segregated wastes.
- (3) Desirable C:N ratio for MSW composts has been indicated to be in the range between 15:1 and 20:1 (Singh, 2004). Accordingly, QC limit for N should be in the range between 0.7 and 0.93% if QC limit for TOC is considered to be 14%. Thus middle value of this range i.e. 0.8% can be considered as QC limit for N in the modified proposal.
- (4) Total K content in the MSW composts was found to be quite low compared to the existing QC limit of 0.83%. Even, the samples produced from well segregated wastes and well managed composting plant (like Vijayawada) had a mean K content of 0.42%. Thus, QC limit for total K content may be modified to 0.4%.

Table 6: Percentage of samples complying Quality Control parameters as per FCO and proposed guidelines in respect of fertilizing parameters

	FCO (1985)			Proposed limit values		
	QC value limit	Within limit (%)	Beyond limit (%)	QC value	Within limit (%)	Beyond limit (%)
Moisture (%)	15-25	44	56	15-25	44	56
Bulk density (g cm ⁻³)	0.7-0.9	56	44	-	-	-
pH	6.5-7.5	62	38	6.5-8.0	97	3
EC (dS m ⁻¹)	≤ 4	88	12	<4	88	12
Total organic C (%)	≥ 16	15	85	≥ 14	24	76
Total N (%)	≥ 0.5	68	32	≥ 0.8	38	62
Total P (%)	≥ 0.22	21	79	≥ 0.22	21	79
Total K (%)	≥ 0.83	9	91	≥ 0.4	68	32
C:N	≤ 20:1	65	35	≤ 20:1	65	35

(b) Compliance in respect of heavy metal contents:

There has been a wide variation in degree of compliance with respect to different heavy metals. While degree of compliance was quite high ($\geq 70\%$) in case of Zn, Cu, Cd and Ni, MSW composts conformed QC guideline poorly in respect of the metals Pb and Cr (Table 8).

The composts prepared from segregated wastes did not contain any other heavy metals, (except Cr) at levels more than the aforementioned limiting values. About half of samples from this category contained Cr more than this limiting value of 50 mg/kg. Further, only about 16% of MSW compost samples analyzed contained all the heavy metals within the QC limit and all of these had been prepared from segregated wastes. Other samples had 1, 2, 3 or 4 heavy metals (out of the 6 analyzed) more than this limiting values and degree of contamination varied widely (Fig. 7). Therefore, the levels of threat perceived by the environment due to their continuous application are also expected to vary.

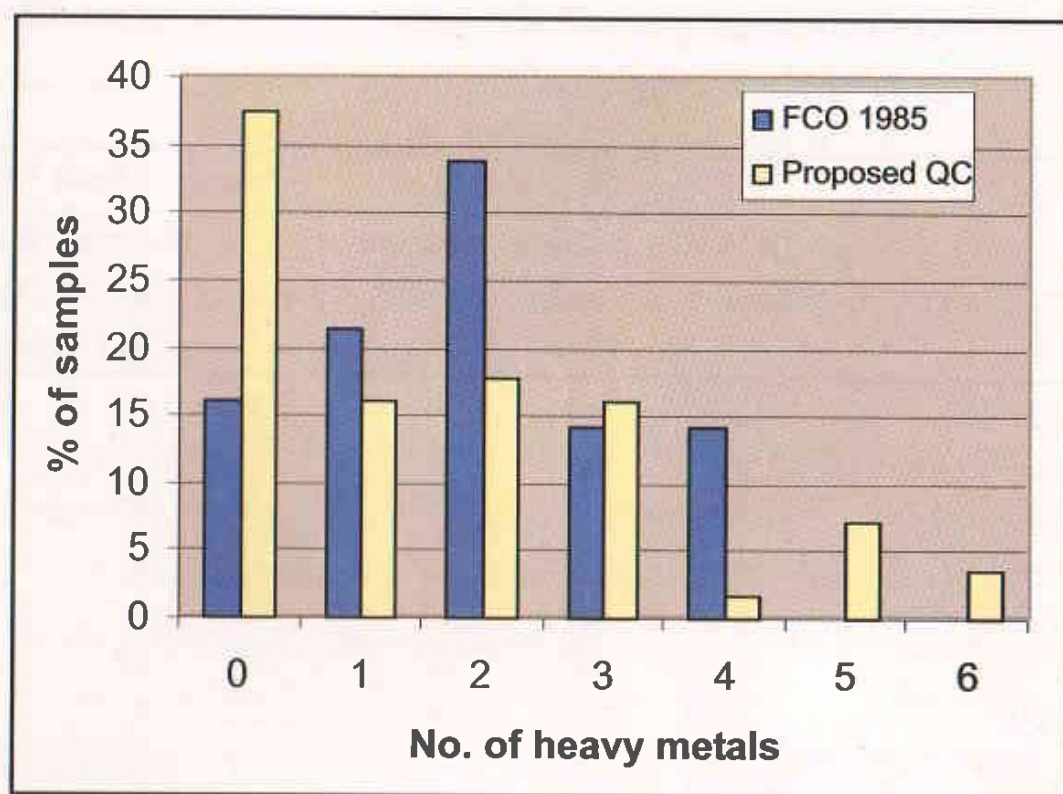


Fig. 7. Percentage of samples having heavy metals more than the quality control limit

Maximum permissible concentration of heavy metals adopted by different countries as regulatory purpose:

The regulatory limiting values of heavy metals defined by different developed countries are presented in Table 7. Wide variation can be observed on this aspect; e.g., maximum and minimum values differing by factors of 53 for Zn, 70 for Cu, 57 for Cd, 18 for Pb, 40 for Ni and 20 for Cr. Such wide variation arises due to different approaches adopted by different countries in developing these guidelines (Harrison and Richard, 2005). These approaches are normally;

- (a) **'risk-based approach'**: Each contaminant should be low enough to achieve a 'no observed adverse effect level' (NOAEL). This has been followed by US-EPA.
- (b) **'No net degradation'**: This is currently being used to regulate composts in the Netherlands, Switzerland, Germany and the Canadian provinces of British Columbia and Ontario. It is based on the philosophy that the levels of contaminants should not be increased over the background soil levels to insure longterm soil fertility. For this reason, quality control limiting values devised with this approach are considerably lower than those devised on the basis of 'risk-based approach'.

Risk based approach for quality control parameter is adopted based on sufficient information to assess the risk adequately and establish thresholds below which risks are considered to be negligible or acceptable. In India, requisite research to establish cumulative loading limit for toxic metals for soils is lacking. In absence of such information, it is desirable to follow 'no net degradation' approach on arriving at quality control standards so as to insure protection of environment and food chain.

Among the quality control parameters defined by different countries based on this approach, the highest values adopted were 500

mg/kg for Zn, 150 mg/kg Cu, 3 mg/kg for Cd, 150 mg/kg for Pb, 100 mg/kg for Ni and 210 mg/kg for Cr. In our study, maximum values of total heavy metal contents in the MSW compost samples prepared from segregated biodegradable wastes were 354 mg Zn/kg, 185 mg Cu/kg, 2.5 mg Cd/kg, 83 mg Pb/kg, 31 mg Ni/kg and 99 mg Cr/kg.

Table 7: Quality control standards in respect of heavy metal contents in composts followed by different countries

Countries	Zn	Cu	Cd	Pb	Ni	Cr
	(mg kg ⁻¹)					
Switzerland	500	150	3	150	100	150
US-EPA	350	100	1.5	150	50	100
US-Florida (Class I)	900	450	15	500	50	-
US-NYS (Class I)	2500	1000	10	250	200	1000
Canada (Ontario)	500	60	3	150	60	50
Canada (British Columbia)	315	100	2.6	150	50	210
Germany	400	100	1.5	150	50	100
EU (Class I)	200	100	0.7	100	50	100
EU (Class II)	400	150	1.5	150	75	150
Austria	1000	400	4	500	100	150
Belgium (food crops)	1000	100	5	600	50	150
Belgium (non food crops)	1500	500	5	1000	100	200
Italy	2500	600	10	500	200	510
Netherlands (Normal)	200	60	1	100	20	50
Netherlands (Very clean)	75	25	0.7	65	10	50
Spain	4000	1750	40	1200	400	750

Considering the QC values set by different countries in conjunction with the analytical results obtained for MSW composts from segregated wastes, some modifications in the quality control limiting values are proposed (Table 8) for use as manure in crop production while protecting our land resources from getting polluted in a reasonably long span of time.

In the proposed modification, limiting values for Zn, Cu and Cd were lower and those for Pb and Cr were higher as compared to the

existing limiting values in the FCO. The 'Schedule II' of Municipal Solid Wastes (Management and Handling) Rules 2000, notified by Ministry of Environment and Forest, New Delhi on 25th September, 2000 issued guideline to Municipal Authority for segregation of solid wastes for their maximum recycling as well as composting of the biodegradable wastes for its reuse in agricultural land. Heavy metals in the composts prepared following such solid waste management guideline are taken as base for redefining QC limit for their maximum permissible contents

Table 8: Percentage of samples complying Quality Control parameters as per FCO and proposed guidelines in respect of heavy metal contents

	FCO (1985)			Proposed QC limit values		
	QC value	Within limit (%)	Beyond limit (%)	QC value	Within limit (%)	Beyond limit (%)
Zn (mg/kg)	≤ 1000	100	0	≤ 500	89	11
Cu (mg/kg)	≤ 300	70	30	≤ 200	54	46
Cd (mg/kg)	≤ 5	98	2	≤ 3	93	7
Pb (mg/kg)	≤ 100	38	63	≤ 150	50	50
Ni (mg/kg)	≤ 50	86	14	≤ 50	86	14
Cr (mg/kg)	≤ 50	23	77	≤ 100	64	36

These limiting values are either at par or more stringent than quality control limiting value of several countries. The purpose behind the modification of the existing QC guideline (i.e. FAI, 2007) is to reduce the proportion of rejection and at the same time, to ensure protection of health of environment, human and food chain. Reduction in the proportion of rejection is desired to encourage recycling of municipal solid waste, reduce the burden on land-filling area, and reduce dependency on fertilizer nutrients in agriculture as well as increasing soil organic C status of India soils, which is generally low.

When the data on heavy metal contents are re-examined through the above proposed limits, about 37.5% of the MSW composts pass

through the quality control guidelines as against 16% passing through the existing guidelines (FAI, 2007). Almost all the MSW composts prepared from the segregated biodegradable wastes meet the proposed QC guidelines with respect to heavy metal contents; whereas, only 44% of such samples met existing QC guideline.

11. Grading of MSW composts for their quality in respect of manurial value and environmental safety

Results of the study clearly indicated that MSW composts prepared by different manufacturers in the country varied widely in potential for nutrient supply, as soil conditioner as well as their potential in contaminating the soil and food chain. Such variations arise mainly due to the type and quality of input feedstocks (i.e. municipal wastes) as well as method of preprocessing and composting. The existing QC guideline only restricts the marketing of MSW composts which are below the certain desired level of different QC parameters and ensures safety of the environment. However, it fails to indicate their overall quality resulting from the use of certain type of input material and following a definite method of composting. Hence, there is a need for grading of composts into different classes for use in different application areas like raising food crops, non-food fibre/flowering crops, establishment of lawns/gardens, reclamation/rehabilitation of certain types of degraded lands and mining areas etc. Composts meeting the stringent standards can be allowed to be used without restriction; while, composts meeting less rigid criteria may be restricted for use in non-food chain crop or other aforementioned purposes and therefore will allow a balancing of agronomic benefit against environmental risks. In its report, Inter-Ministerial task force constituted on INM using city compost at the directives of Honorable Supreme Court of India, also recommended formulation of grades under regulatory provisions.

Thus, an attempt has been made to develop a method of indexing which can guide the manufacturers, consumers as well as planners to

evaluate the overall quality of the MSW composts and help them in their decision making.

(a) Grading according to fertilizing and soil conditioning potential

Contents of organic matter as well as major nutrients N, P and K in the MSW composts were found to vary widely and therefore, their potential for increasing crop production also varied considerably. An attempt has been made to compute a single numerical value representing 'Manurial value index' which can appropriately describe potential of the MSW composts in improving soil fertility of agricultural land. For this, data pertaining to organic matter content, total N, P and K contents as well as C:N ratio of the composts, which are responsible for improving fertility and physical health of soil, are used to compute 'Manurial value index' of MSW composts. Each analytical data are assigned a 'score' as per the category given in Table 9. On the basis of scientific knowledge on their role in improving soil fertility, each of these fertility parameters was assigned a 'weighing factor'.

Table 9: Criteria for assigning 'Weighing factor' to fertility parameters and 'Score value' to analytical data

	Score value					Weighing factor
	5	4	3	2	1	
Total organic C (%)	>25.0	20.1-25.0	15.1-20.0	10.1-15.0	<10.1	5
Total N (%)	>1.25	1.01-1.25	0.81-1.00	0.51-0.80	<0.51	3
Total P (%)	>0.60	0.41-0.60	0.21-0.40	0.11-0.20	<0.11	2
Total K (%)	>1.00	0.76-1.00	0.51-0.75	0.26-0.50	<0.26	1
C:N	15.1-20.0	20.1-25.0, <15.1	25.1-30.0	30.1-35.0	>35	1

The 'Manurial value index' value of the MSW composts is computed using the formula:

$$\text{'Manurial value index'} = \frac{\sum_{i=1}^n S_i W_i}{\sum_{i=1}^n W_i}$$

Where, ' S_i ' is score value of analytical data and ' W_i ' is weighing factor of the ' i 'th fertility parameter.

Results of computation indicated that 'Manurial value index' values of MSW composts varied from 1.42 to 3.92 with a mean value of 2.26 (in 5.0 point scale). The highest and the lowest mean index values were observed in case of medium cities (2.38) and metro cities (2.00) respectively (Fig. 8). Smaller cities with less than 1 million populations recorded on an average 8.8% higher mean 'Manurial value index' value as compared to bigger cities with more than 1 million populations. Composts prepared from segregated wastes recorded about 41.4% and 32.3% more index values compared to those prepared from non-segregated and partially segregated wastes, respectively. Composts prepared from source-segregated wastes (at house hold level) in Vijaywada (A.P.) recorded the highest 'Manurial value index' value of 3.92.

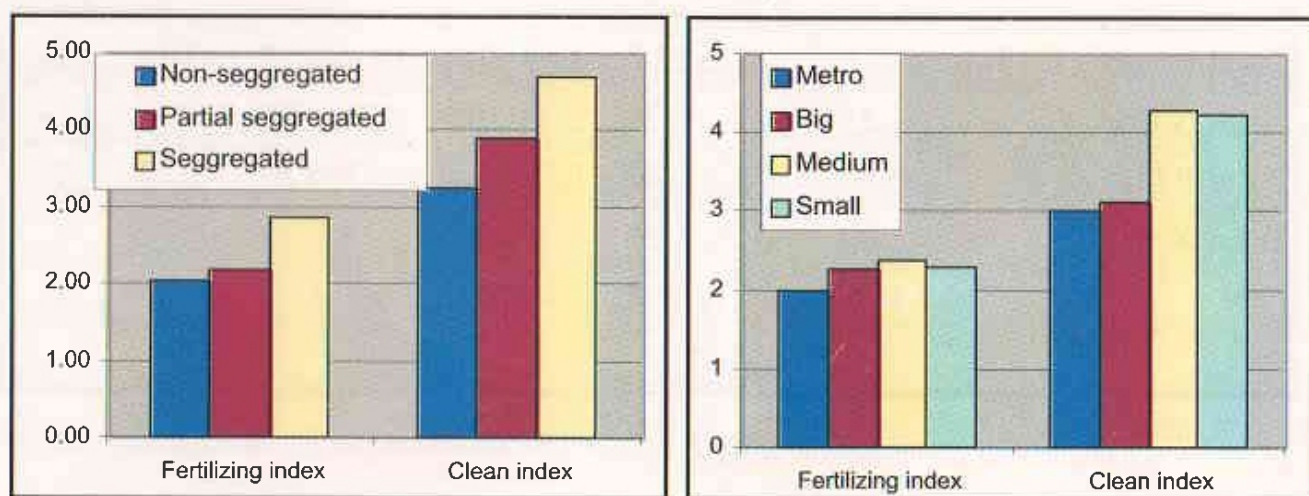


Fig 8. Effect of segregation of wastes and city size on mean 'Manurial value index' and 'Clean index' values of MSW composts

(b) Grading according to heavy metal pollutant content

Degree of heavy metals contamination has been found to vary widely among the different MSW composts; thereby posing different degree of threat to the environment. An attempt is made in this study to award 'Clean index' to each of MSW composts. Score values were given to each analytical value of the heavy metals as per following scheme. Each heavy metal was assigned 'Weighing factor' on the basis of available information on the level of toxicity to human as well as extent of availability in soil upon addition (Table 10). 'Clean index' value was calculated as per the following formulae. Higher score is ascribed for less heavy metals content. Thus, composts with less heavy metal contents attain higher value of 'Clean index'.

$$\text{'Clean index'} = \frac{\sum_{i=1}^n S_i W_i}{\sum_{i=1}^n W_i}$$

Where, 'S_i' is score value of analytical data and 'W_i' is weighing factor of the 'i'th heavy metal.

Table 10: Scoring criteria for computing 'Clean index' of MSW composts

Heavy metal	Score value					Weighing factor
	5	4	3	2	1	
Zn (mg/kg)	<151	151-300	301-500	501-700	>700	1
Cu (mg/kg)	<101	101-150	151-300	301-500	>500	2
Cd (mg/kg)	<1.1	1.1-2.0	2.1-3.0	3.1-4.0	>4.00	5
Pb (mg/kg)	<51	51-100	101-200	201-400	>400	3
Ni (mg/kg)	<21	21-40	41-80	81-160	>160	1
Cr (mg/kg)	<41	41-80	81-160	161-240	>240	3

Results, thus obtained, indicated that 'Clean index' varied from 1.33 to 5.00 with a mean value of 3.62 (in the 5.0 point scale). The highest

mean index was observed in case of medium cities (4.16) followed by small cities (4.08), big cities (2.95) and metro cities (2.83) (Fig. 8). Like wise, composts prepared from non-segregated wastes had the lowest 'Clean index' value (3.10) in comparison with those prepared from partially segregated wastes (3.68) and segregated wastes (4.59). The composts, having all the heavy metals below the proposed quality control limiting values, had index values ranging from 3.67 to 5.00 with an average value of 4.40.

From the critical analysis of the results, it has been found that some of composts though attained high value of the 'Clean index' (> 4.00), these could not pass through the proposed quality control standards due to presence of one of the metals concentration beyond the permissible limit. Due to having quite low concentration of all other heavy metals, such composts (with 'Clean index' value more than 4.0) can safely be utilized under some restricted situations like for growing non-food crops like floriculture, fibre crop, agroforestry plantation or lawn establishments etc. This will help in recycling of city wastes and lessen the burden of land filling.

12. Compost quality index

While 'Manurial value index' can be taken as a measure of nutrient supplying potential, 'Clean index' value can be used by regulatory authority for restricting the entry of heavy metals into sensitive components of environment (like agricultural land and water bodies). An integration of these two indices can obviously indicate overall quality of MSW composts. Thus, 'Compost quality index (CQI)' had been computed as sum of 'Manurial value index' and 'Clean index' values for each of the compost samples.

Compost quality index (CQI) = 'Manurial value index' + 'Clean index'

Results indicate that average CQI for MSW composts produced in the smaller cities (population <1million) was about 28% higher than

those produced in the larger cities (population >1million). Also, MSW composts produced from segregated wastes had an average COI of 7.46 which was about 45.5% and 27.5% higher compared to those produced from respectively non-segregated wastes and partially segregated wastes. Further, source segregation of wastes at house-hold level (as followed in Vijaywada, Suryapet and Namakkal Municipality) resulted about 15% higher CQI in composts as compared to MSW composts produced from wastes collected from selected sources known to generate mainly biodegradable wastes (like hotels & restaurants, vegetable markets, slaughter house etc.). This indicates that segregating out non-biodegradable fraction from municipal solid wastes, preferably at household level can improve quality of composts in India.

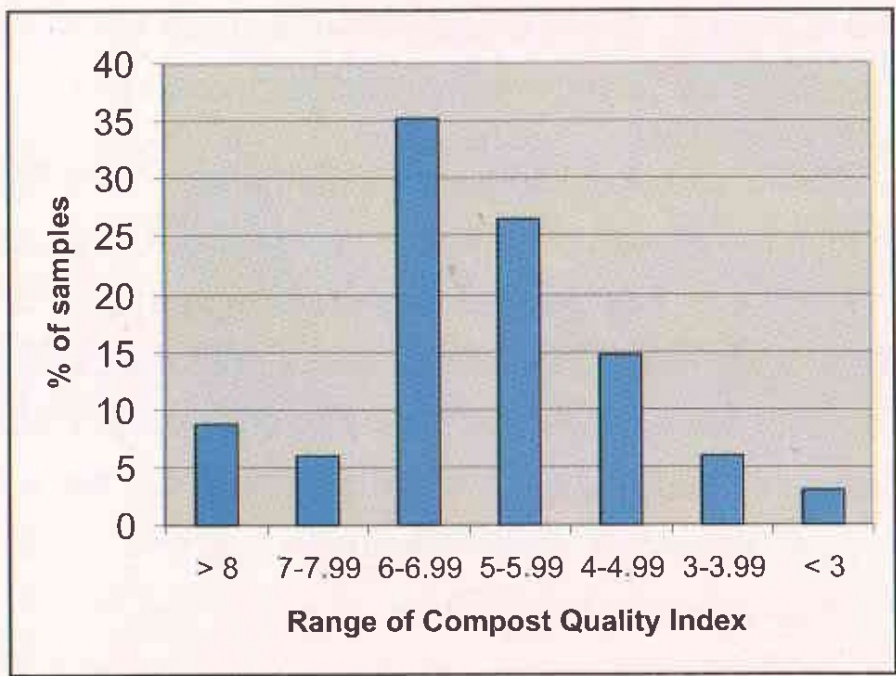


Fig. 9: Percentage of samples belonging to different range of compost quality indices

13. Classification of MSW composts on the basis of quality indices values

On the basis of critical analysis of 'Manurial value index', and 'Clean index' values of MSW composts produced through different processing methods, different classes of composts has been proposed

(Table 11) for their use in different application areas as well as suitability as marketable products. The bases for such classifications are:

- (a) All the MSW composts, to be permitted for marketing, should pass all the QC parameters as per the regulatory limits of The Fertilizer (Control) Order.
- (b) Product should be allowed to market only if, the value of 'Fertilizing index' exceeds 3.00. This is because if the product meets all the quality control limits with respect to fertilizing parameters viz., total organic C, total N, P, K and C-N ratio, it will score a minimum 'Fertilizing index' value of 3.00.
- (c) MSW composts graded under Classes A, B, C and D may be allowed to market. These classes indicate their overall quality and thus, may help the farmers in their decision-making.
- (d) Several MSW compost samples (graded under class RU-1) scored high 'Clean index' values but failed to qualify QC protocol due to having at least one heavy metal beyond the permissible limit. Such composts with high 'Fertilizing index' values can be used for growing non-food crops (including fodder crops) with periodic monitoring of soil quality if used repeatedly. This will enhance recycling of municipal solid wastes to a greater extent and thus reduces the burden on land filling.
- (e) Although composts graded under class RU-2 contain heavy metals within QC limit, these should not be allowed to market due to having low manurial value.
- (f) Composts (graded under Class 'RU-3') containing high amount of heavy metals may only be allowed for one-time application like developing lawns and rehabilitation of degraded lands etc.

Table 11. Classification of MSW composts for their marketability and use in different area

Class	'Compost quality index' value	Manurial value index	Quality control compliance	Remark
A	≥ 8.0	≥ 3.50	Complying for all heavy metal parameters	Best quality. High Manurial value potential and low heavy metal content
B	≥ 8.0	3.00 to <3.50	Complying for all heavy metal parameters	Very good quality. Medium fertilizing potential and low heavy metal content
C	6.00 to <8.00	≥ 3.50	Complying for all heavy metal parameters	Good quality. High fertilizing potential and medium heavy metal content
D	6.00 to <8.00	3.00 to <3.50	Complying for all heavy metal parameters	Medium quality. Medium fertilizing potential and medium heavy metal content.
RU-1	≥ 7.00	≥ 3.50	Not complying for all heavy metal parameters	Should not be allowed to market. Restricted use. Can be used for growing non-food crops Requires periodic monitoring of soil quality if used repeatedly.
RU-2	–	< 3.00	Complying for all heavy metal parameters	Unrestricted use but should not be allowed to market.
RU-3	< 7.00	< 3.50	Not complying for all heavy metal parameters	Can be used only for one-time application like developing lawns, rehabilitation of degraded lands.



Photo 12: Decomposing of non-segregated municipal solid wastes in open area in Dhapa of Kolkata city lead to production of poor quality composts (Class RU-3) with low manurial value and high heavy metal content



Photo 13: Vermicomposting of well-segregated municipal wastes in pits under covered condition at Maylampedu ward of Vijaywada city produced 'Class A' compost with manurial value and low heavy metal contents

Re-examination of the data showed that among the MSW compost samples collected from different cities, two samples (both from Vijaywada) could be classified under 'Class A', one sample (from Tiruppur) under 'Class B', and two samples (from Trivandrum and Nashik) under 'Class D'. About 32% samples were classified under Class 'RU-2' due to low manurial value and 53% (classified under Class 'RU-3') were found unsuitable for repeated application due to heavy metals content.

It should be mentioned that all the 3 samples, graded under 'A' and 'B' were prepared from segregated wastes and both the samples under 'Class D' were prepared from partially segregated wastes.

Above results thus showed that overall quality of the composts manufactured in the country are 'poor quality' and unsuitable for marketing. A serious attention is required for improving the existing solid waste management system, particularly in pre-processing segment (i.e., segregation of biodegradable fraction) so that MSW composts can find a place in the integrated nutrient management system for crop production in our country.

14. Salient findings and conclusions

- Municipal solid waste composts are produced in India mostly from non-segregated wastes with very little processing before composting process. Organic matter as well as major nutrients N and P contents in composts prepared from such wastes are generally low as compared to those prepared from agricultural wastes.
- Wide variations in different heavy metals contents had been observed in MSW composts produced in the country. Although no significant variations had been observed in fertility parameters like organic matter, total N, P and K contents in MSW composts

produced in cities with different populations, larger cities have been found to contain higher contents of different heavy metals.

- Segregation of municipal wastes for biodegradable components before composting resulted significant improvement in total organic matter, total N and total P contents in the finished products. This also caused lower contents of heavy metals as compared to those produced from non-segregated and partially segregated wastes.
- Thus, integrated solid waste management which involves providing separate waste bins to every households in the municipality for keeping wet waste (i.e. kitchen waste) and other dry wastes separately, collecting and transporting the wet waste separately in the composting yard came out as best option for producing good quality waste.
- Quite a large proportion of MSW composts did not conform to the quality control guidelines of 'The Fertiliser (Control) Order 1985' in respect of total organic C, total P, total K as well as heavy metals Pb and Cr. Even majority of MSW composts prepared from segregated wastes failed to comply with QC limits in respect of total organic C, total K contents and Cr contents.
- Keeping in view of the need to redefine QC limiting values, modification has been proposed for several physical, chemical, heavy metal content parameters on the basis of available information on QC limit values defined by different countries as well as analytical results of MSW composts collected from different composting plants of municipalities of 28 cities of the country.
- However, there is a need to develop database on the cumulative heavy metal loading limits for soil based on which QC limit values for different heavy metals can be refined further.

- An approach has been proposed to grade the MSW compost samples according to their fertilizing potential as well as potential for contaminating soil and food chain. In this direction, methodology for computing 'Manurial value index' (indicator for manurial value), 'Clean index (indicator for heavy metal threat)' and 'Compost quality index' has been indicated. On the basis of these indices, different classes of MSW composts have been proposed along with basis for classification and applicability in different areas.
- Majority of the composting plants have been found to produce poor quality composts in terms of low manurial value and high heavy metal contents due to inappropriate processing of wastes during composting. There is a need to develop a strategy for utilizing such wastes for alternative use (other than for growing food crops) like reclamation and rehabilitation of severely degraded land, establishment of forestry, developments of parks, lawns etc.
- There is a need for comprehensive policy on periodic monitoring of soil health of the land receiving MSW composts continuously so that build up of heavy metals to a toxic level can be avoided.
- Soil has an inherent capacity to immobilize the metals so that they become unavailable for absorption and such capacity differs with soil types depending upon their chemical and mineralogical properties. Researches are required to identify sensitive soils having low metal immobilizing capacity where application of MSW composts can be prohibited.

15. Recommendation

- (1) Promoting door-to-door collection of segregated wastes: Every household in the municipality should be provided with two separate colored waste bins for keeping kitchen wastes and other

wastes separately. Biodegradable kitchen wastes should be transported to composting yard and other dry wastes should be recycled as much as possible.

- (2) Sources generating mainly biodegradable wastes like vegetables markets, fruit markets, fish markets, hotels and restaurants, slaughter-houses should be identified and separate system should be developed to collect wastes from these places for producing good quality municipal solid waste composts.
- (3) Composting in pits using earthworms and providing shed to the composting yard can produce good quality municipal solid waste composts.
- (4) Policy steps need to be taken for reducing the non-biodegradable wastes like plastics, metal, glass etc. Use of ultra-thin plastics should be banned throughout the country and manufacturing of carry bags made of biodegradable substances should be promoted through incentives and subsidies.
- (5) As pace of compliance to MSW Rules 2000 is very slow, majority of the cities are expected to produce poor quality composts in near future also. A policy needs to be undertaken for alternate use of such composts, like rehabilitation of degraded lands, establishment of municipal gardens, agro-forestry etc., so that burden on already shrunk land filling sites can be reduced. In this direction, categorization into different classes as proposed in Table 11, can be an useful guide.
- (6) As assessment of MSW compost quality is very important for monitoring and regulatory purpose, there is a need to create a centralized 'Quality control monitoring laboratory' in the country to keep an eye on the quality of composts produced by different manufacturers, to find out the changing nature of heavy metal contents with time as well as to provide research back-up for improving the MSW compost quality.

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Strategy for maximum and safe recycling of municipal solid wastes through composts of different quality

MSW Composts							
Class	Class 'A'	Class 'B'	Class 'C'	Class 'D'	Class 'RU-1'	Class 'RU-2'	Class 'RU-3'
Manurial value	High	High	Moderate	Moderate	High	Low	Low to moderate
Heavy metals content	Low	Medium	Low	Medium	Low (except for few)	Low to medium	High
Utilization strategy	For all crops, preferably for high value crops	For all crops	For all crops	For all crops	Only for non-food crops like fibre crop, floriculture etc.	For all crops	One time application in developing lawns, rehabilitation of degraded land.
Quality control limits for heavy metals	Must meet QC limit for all heavy metals	Must meet QC limit for all heavy metals	Must meet QC limit for all heavy metals	Must meet QC limit for all heavy metals	May contain 1 or 2 heavy metals beyond QC limit	Must meet QC limit for all heavy metals	Do not meet QC limit for all heavy metals
Periodic monitoring of heavy metals build-up in soil	Not required	Not required	Not required	Not required	Required	Not required	Not required
Permission for selling in markets	May be permitted				Should not be permitted		

